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Produced for/Distribution List: Dr. Julie Lefebvre, Director General Science and Technology Joint Force Development (DGSTJFD)

Scientific Letter

On the Suitability of Mobile Cloud Computing at the Tactical Edge

Background

On 21 May 2013, DGSTJFD requested advice from the Canadian National Lead of The Technical Cooperation Panel (TTCP) Command, Control, Communications and Intelligence (C3I) Action Group 2 (AG2) on Cloud Computing regarding how cloud computing could be used in a tactical environment to garner important Command and Control (C2) and situational awareness information. In response to this request, and based on the recommendations from an AG2 Technical Report on coalition cloud computing [1], scientists in the Cyber Operations and Signals Warfare (COSW) Section of Defence Research and Development Canada (DRDC) contracted a preliminary study [2] to assess the use of tactical clouds in enhancing warfighter effectiveness. The study produced a number of diverse use-cases, architectures, and scenarios for tactical cloud computing.

Before the study was finalised, and as a result of concurrent interest from TTCP C3I Technical Panel 2 (TP2) on Communications, Networking, and Dissemination, the Canadian National Leads from TP2 (Tricia Willink) and AG2 (Kathryn Perrett) arranged an initial meeting on 16 December 2013, to discuss a coordinated approach to potential future efforts. A workshop on the topic of tactical cloud computing was subsequently held on 9 January 2014, to bring together scientific experts in tactical communications and networking from DRDC and the Communications Research Centre (CRC). The workshop used a draft of the DRDC study as a starting point to explore two questions:

1) In what situations would cloud computing benefit military communications networks at the tactical edge, where the network is bandwidth constrained?
2) What are the S&T challenges associated with bringing cloud computing to the tactical edge?

This Letter summarises the outcomes of the joint workshop and provides a recommendation on a way forward for assessing the suitability of mobile cloud computing at the tactical edge.

Statement of Results

Two broad types of tactical cloud architectures from [2] were considered for discussion at the workshop:

- Conventional cloud: this architecture uses cloud computing technologies and concepts in single-point (possibly mobile) deployments to provide enhanced computation and storage capabilities to operational environments. Examples of such an architecture include Strategic cloud (deployed at a headquarters), Forward Operating Base (FOB) cloud (Figure 1), and Cloudlet (deployed on a single vehicle).

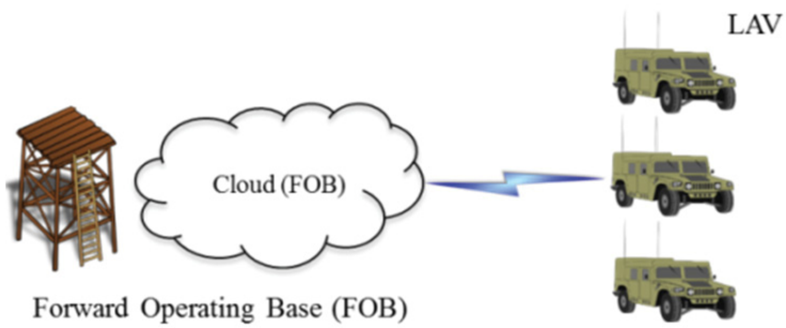

Figure 1: *This is an example of a FOB cloud, a sample use-case scenario for conventional cloud architectures.*

- Dynamic tactical cloud: this architecture includes a (variable) number of cloud-enabled devices in an ad hoc network. As the devices approach one another, they form a larger “cloud” with enhanced processing and storage capabilities. Examples of such an architecture include a Battlegroup cloud (Figure 2) and vehicle ad hoc network (VANET) cloud.

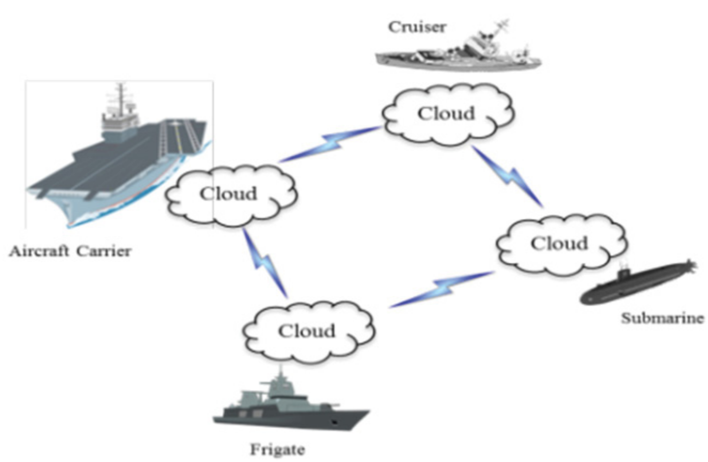

Figure 2: *This is an example of a Battlegroup cloud, a sample use-case scenario for dynamic tactical cloud architectures.*

> **A note on cloud computing:** The National Institute of Standards & Technologies (NIST) defines cloud computing as "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources … that can be rapidly provisioned and released with minimal management effort" [3]. To an end user or service recipient, a cloud appears as a centralized architecture, even though the internal architecture of the cloud may be physically and virtually distributed. Mobile Cloud Computing (MCC) is a concept in which a mobile entity can be considered as either a physical mobile device or a mobile computing/storage software agent within the virtualized cloud resource provisioning system – part of the cloud [4].

From a tactical communications point of view, the first architecture (depicted in Figure 1) was considered equivalent to the concept of moving datacentres and processing closer to the tactical edge, as shown in Figure 3. Whether or not cloud computing is used to provide the (single-point) computing and storage capability, the workshop concluded that the more germane question is, "When should processing and storage be moved closer to the tactical edge?". This architecture was found not to present unique (S&T) challenges; the challenges are not different from those that already exist with a traditional philosophy of processing at, or close to, the tactical edge. In addition, it was recognized that this architecture may pose additional security risks for vulnerable computing equipment that may not have the benefits of physical security, in the form of fences and gates.

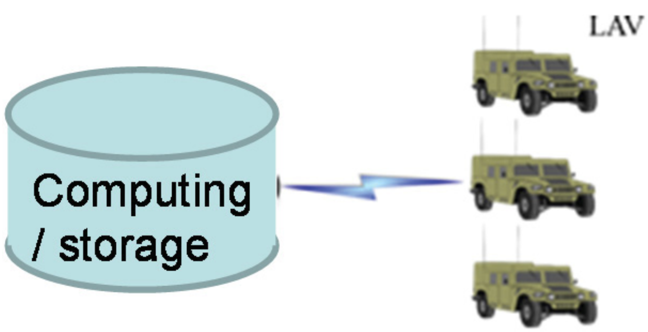

Figure 3: *This is an example of a non-cloud architecture with the datacentre closer to the tactical edge.*

The second architecture (depicted in Figure 2) was found to have tangible S&T challenges. The dynamics of inter-cloud interactions and the ability to synchronize MCC services over tactical links were found to be challenging. While current cloud computing technology readily allows architectures with distributed (non-co-located) computing, it is unclear if this technology could withstand the intermittent connectivity of tactical links. The S&T challenges also extend to the design of future military applications at the tactical edge, which may require enhanced processing and storage services.

Discussion of Results

A list of potential military software applications executed by mobile units at the tactical edge that could benefit from MCC services were identified during the workshop. Mobile applications with the following characteristics would benefit most from a nearby MCC: the application requires a significant amount of processing power, the application does not require a large communications overhead, and the application may call on a large database. It was recognized that application designers would need to take into account a balance between on-board processing (done by a mobile unit), off-board processing (done by the MCC), and communications overhead (between the mobile and MCC). The following is a sample of military applications that may potentially require MCC services:

- Language translation;
- Localization and geolocation;
- Facial recognition (photo identification/classification);
- Intelligence, Surveillance, and Reconnaissance (ISR); and
- Fusion of Electronic Warfare (EW) information.

It is not yet clear if MCC is the proper technology to apply to the bandwidth constrained environment of the tactical edge, nor is it clear how best to optimize military applications for MCC. The challenges to support service oriented architectures (SOAs) on Mobile Ad hoc Networks (MANETs) with communication links of intermittent connectivity at the tactical edge should be investigated before, and as a prerequisite to, any investigation to support virtualized services of MCC. In addition, future military applications at the tactical edge that may require MCC services should be identified and tested in simulation environments if, and only if, MCC is proven to be a viable SOA supported on MANETs.

Conclusion

Based on the findings of the contracted study and the results of the workshop, the following conclusions are drawn:

- Tactical applications that could benefit most from MCC are those with large processing overhead, low bandwidth requirements, and a need for large database support (e.g., facial recognition, language translation).
- The effect—specifically on the communication links—of supporting these applications at the tactical edge requires further investigation, as this may affect the type of architecture (MCC or otherwise) that is selected.
- Dynamic cloud computing architectures provide significant S&T challenges due to the variability of link quality in tactical environments, though their feasibility for tactical applications is currently unknown.
- Conventional cloud computing architectures provide a means for bringing processing and data closer to the tactical edge in order to deliver C2 and situational awareness, though other non-cloud solutions could potentially achieve a similar result. The question of how much data and processing is needed at the tactical edge must be addressed with further studies before choosing cloud or other technologies to achieve this effect.

As the maturity level of mobile cloud computing increases, it may provide some tangible benefits for bringing data and processing to the tactical edge. However, this will require a re-examination of how applications are developed for these environments.

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References

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